

Assessment of the Adequacy of the Appendix F
Quality Assurance Procedures for Maintaining
CEMS (Continuous Emission Monitoring Systems)
Data Accuracy: Status Report 2

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ASSESSMENT OF THE ADEQUACY OF THE APPENDIX F QUALITY ASSURANCE
PROCEDURES FOR MAINTAINING CEMS DATA ACCURACY:
Status Report 2

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SECTION 1

INTRODUCTION

The U. S. Environmental Protection Agency (EPA) Quality Assurance Division is involved in the development of "Appendix F - Quality Assurance Procedures: Procedure 1 - Quality Assurance Requirements for Gas Continuous Emission Monitoring Systems (CEMS) for Compliance" for future inclusion in 40 CFR 60. The most recent draft of Appendix F, Procedure 1 requires the emission source owner or operator:

1. to develop and implement a quality control program that includes written procedures for key CEMS operations,
2. to calculate monthly data precision for each CEMS channel from results of daily span checks, and
3. to determine quarterly the accuracy of each CEMS. Two methods are provided in Procedure 1: a cylinder gas audit (CGA) for CEMS capable of accepting calibration gases, and a relative accuracy audit (RAA) for all CEMS.

To evaluate the adequacy and effectiveness of the specific CEMS data accuracy assessment procedures included in Procedure 1, a field performance audit program is being conducted. The program involves periodic testing of a number of operational CEMS installed at flue gas desulfurization (FGD) equipped fossil-fuel-fired steam generators. A report entitled, "Assessment of the Adequacy of the Appendix F Quality Assurance Procedures for Maintaining CEMS Data Accuracy, Status Report 1" (January 1983), presents the test results obtained through April 1982 and detailed background information for the CEM performance audit program.

Status Report 2 presents updated RAA and CGA results for all CEM tests conducted through November 1983. Section 2 presents RAA results, and Section 3 presents CGA results. A comparison of RAA and CGA results for those CEMS that accept calibration gases is provided in Section 4. Conclusions regarding the adequacy of the Appendix F, Procedure 1 requirements are not included in Status Report 2. Such conclusions will be developed and included in future reports subsequent to the acquisition of additional field testing results and completion of statistical analysis of all test results obtained during this project.

In this report, references to Appendix F, Procedure 1 relate to the draft regulatory package dated December 12, 1983.

SECTION 2

RELATIVE ACCURACY AUDIT (RAA)

2.1 RAA Requirements in Appendix F, Procedure 1

The requirements of Appendix F, Procedure 1 related to the RAA are:

"6.1 Accuracy Assessment Procedure. Within the first 2 months of each calendar quarter, audit each CEMS at least once using a RAA, CGA, or EPA-approved alternative as follows:

6.1.1 Relative Accuracy Audit. The procedure for the RAA is the same as for the relative accuracy test described in the applicable performance specification (e.g., Performance Specification 2 for SO₂ and NO_x and Performance Specification 3 for O₂ and CO₂), except six rather than nine sets of measurements are required...

6.2 Corrective Action for Excessive Inaccuracy. If the relative accuracy (RA) exceeds 25 percent using the RAA or 10 percent of the applicable standard, whichever is greater, the CEMS is 'out-of-control.' For SO₂ emission standards between 130 and 86 ng/J (0.30 and 0.20 lb/million Btu) use 15 percent of the applicable standard; below 86 ng/J (0.20 lb/million Btu), use 20 percent of emission standard."

2.2 Summary and Discussion of RAA Results

Tables 1 through 7 summarize RAA results for seven SO₂ and four NO_x CEMS installed on seven coal-fired boilers equipped with FGD systems. As nearly as possible, the RAAs were conducted every 3 months (in accordance with the quarterly audit requirement of Appendix F) to assess the accuracy of the CEMS data. However, of the seven sources, Source P withdrew from the program after the first audit was conducted, and Source W was only recently added to the audit program. Periodic RAAs were conducted for the other five CEMS.

The results of 50 SO₂ and NO_x system RAAs show that 38 of the 50 CEMS audited were within the $\leq 25\%$ RA limit. The $\leq 25\%$ RA limit for six test runs specified in Appendix F for CEMS corresponds to the $\leq 20\%$ RA limit allowed in Performance Specification 2 for RA tests for nine test runs. Data supporting this relationship are presented in the January 1983 Status Report 1.

Of the 12 audits that were outside the $\leq 25\%$ RA limit, four were consecutive audits at Source N, which is equipped with a Contraves Goerz GEM-1 SO₂/CO₂ monitoring system. During the period of these four audits, efforts were made by source personnel and the monitor manufacturer to bring the monitoring system to an "in-control" status; however, the monitor remained in an "out-of-control" state. Testing was discontinued after the fourth consecutive failure of the CEM to meet the RA limit. Subsequently, the monitor manufacturer recommended another source, which is equipped with a Contraves Goerz GEM-100 SO₂/NO/CO₂ monitoring system, to replace the "out-of-control" monitoring system at Source N; the audit program was initiated at this source (Source C) in May 1983. The results of three audits of the GEM-100 at Source C demonstrated that the SO₂ monitoring system was within the RA limit. However, the NO CEM, which is not normally used by the source, failed to meet the RA limit during the first two audits.

Twenty-eight SO₂ and NO system RAAs on two Lear Siegler SM810 SO₂/NO and CM50 O₂ monitoring systems installed on two different units at the same site (i.e., Sources S1 and S2) were conducted over a 2-year period. The LSI SO₂/NO monitoring system at Source S2 was within the < 25% RA limit for 15 of 16 audits. The SO₂ monitoring system passed all tests; the NO monitoring system failed only one audit. The other LSI monitoring system, Source S1, was within the < 25% RA limit for 9 out of 12 audits. The SO₂ CEMS failed two successive RAAs, and the NO CEMS failed one RAA. The results for two of these audits (i.e., 26.7% and 25.9%) only slightly exceeded the 25% RA limit.

The DuPont SO₂ monitoring system met the RA limit for five of seven audits that were conducted during the 34-month testing program at Source A.

The EDC SO₂ monitoring system met the RA limit during the one audit that was conducted for this monitoring system at Source P.

Both the SO₂ and NO_x monitoring systems installed at the FGD inlet at Source W were within the RA limit during an initial August 1983 audit.

All of the sources selected for this audit program except Source W are equipped with FGD systems and are subject to Subpart D, 40 CFR 60. (Source W is subject to Subpart Da and became operational shortly before the initial audit was conducted.) Except for data from Source W, the data provided by the subject CEMS are not used to demonstrate compliance with emission limits. In addition, none of the sources that participated in this study are currently subject to CEM quality assurance (QA) requirements, nor are they required to initiate corrective action based on the test results obtained during this study. Thus, the test results are not necessarily representative of the improved level of CEM performance that is expected to be achieved when Appendix F or other effective QA procedures are required and where SO₂ and NO_x CEM data are used for continual demonstration of compliance with 30-day rolling average emission standards.

TABLE 1. SIX-RUN RELATIVE ACCURACY AUDIT RESULTS
FOR CEMS INSTALLED ON COAL-FIRED FGD EQUIPPED BOILER:
SOURCE A, DUPONT 460 SO₂ - THERMOX O₂ CEMS^a

Test date	SO ₂ /O ₂ SYSTEM	
	Emission level (lb/10 ⁶ Btu)	Relative accuracy ^b (%)
1/81 ^c	0.40	(-) 8.0
11/81	0.57	(+) 9.5
4/82	0.39	(+)19.7
8/82	0.49	(+)34.7
11/82 ^d	--	--
4/83	0.47	(-)16.4
7/83	0.46	(+)18.7
11/83	0.41	(+)53.7

^aSO₂ monitor range: 0 - 400 ppm SO₂; O₂ monitor range: 0 - 25% O₂.

^bThe (+) or (-) indicates whether the monitor responses were greater than, (+), or less than, (-), the reference method test results.

^cThe test data for 1/81 were obtained from the initial monitoring system Performance Specification Test. All subsequent test results were obtained during the implementation of the Appendix F performance audit program.

^dNo valid sampling data could be obtained during this audit because of a scrubber malfunction which resulted in excessive levels of scrubber liquor at the sampling location.

Note: Emission levels expressed in pounds of pollutant per million Btu were computed using the procedures of Reference Method 19 and the test results obtained during the six-run relative accuracy audit.

TABLE 2. SIX-RUN RELATIVE ACCURACY AUDIT RESULTS
FOR CEMS INSTALLED ON COAL-FIRED FGD EQUIPPED BOILER:
SOURCE P, EDC DIGI SERIES 1400 SO₂/CO₂ CEMS^a

SO ₂ /CO ₂ SYSTEM		
Test date	Emission level (lb/10 ⁶ Btu)	Relative accuracy ^b (%)
7/81 ^c	1.06	(-)12.3

^aSO₂ monitor range: 0 - 1000 ppm SO₂; CO₂ monitor range: 0 - 25% CO₂.

^bThe (-) indicates that the monitor response was less than the reference method test result.

^cSource P withdrew from the Appendix F audit program after the first audit.

Note: Emission levels expressed in pounds of pollutant per million Btu were computed using the procedures of Reference Method 19 and the test results obtained during the six-run relative accuracy audit.

TABLE 3. SIX-RUN RELATIVE ACCURACY AUDIT RESULTS
FOR CEMS INSTALLED ON COAL-FIRED FGD EQUIPPED BOILER:
SOURCE N, CONTRAVES GOERZ GEM-1 SO₂/CO₂ CEMS^a

SO ₂ /CO ₂ SYSTEM		
Test date	Emission level (lb/10 ⁶ Btu)	Relative accuracy ^b (%)
9/80 ^c	0.92	(+) 18.8
7/81	0.43	(+) 12.3
12/81	0.45	(+) 12.8
3/82	0.57	(+) 61.8
6/82	0.34	(+) 146.8
9/82 ^d	0.54	(+) 34.8

^aSO₂ monitor range: 0 - 4000 ppm SO₂; CO₂ monitor range: 0 - 20% CO₂.

^bThe (+) or (-) indicates whether the monitor responses were greater than, (+), or less than, (-), the reference method test results.

^cThe test data for 9/80 were obtained from the initial monitoring system Performance Specification Test. All subsequent test results were obtained during the implementation of the Appendix F performance audit program.

^dThe Appendix F audit program was discontinued at Source N after the 9/82 audit.

Note: Emission levels expressed in pounds of pollutant per million Btu were computed using the procedures of Reference Method 19 and the test results obtained during the six-run relative accuracy audit.

TABLE 4. SIX-RUN RELATIVE ACCURACY AUDIT RESULTS
FOR CEMS INSTALLED ON COAL-FIRED FGD EQUIPPED BOILER:
SOURCE S1, LSI SM810 SO₂/NO - CM50 O₂ CEMS^a

SO ₂ /O ₂ SYSTEM		
Test date	Emission level (lb/10 ⁶ Btu)	Relative accuracy ^b (%)
7/81	1.10	(+) 18.6
12/81	1.18	(+) 8.9
5/82	1.10	(+) 26.7
11/82	0.87	(+) 35.9
2/83 ^c	—	—
5/83	1.14	(-) 12.2
8/83	0.95	(+) 22.0
NO/O ₂ SYSTEM		
Test date	Emission level (lb/10 ⁶ Btu)	Relative accuracy ^b (%)
7/81	0.74	(-) 4.3
12/81	0.56	(+) 22.9
5/82	0.73	(-) 16.4
11/82	0.57	(+) 10.8
2/83 ^c	—	—
5/83	0.58	(+) 25.9
8/83	0.64	(+) 9.0

^aSO₂ monitor range: 0 - 1500 ppm SO₂; NO monitor range: 0 - 1000 ppm NO;
O₂ monitor range: 0 - 10% O₂ and 0 - 25% O₂.

^bThe (+) or (-) indicates whether the monitor responses were greater than, (+), or less than, (-), the reference method test results.

^cOnly three sampling runs were completed. During the RAA, the boiler was shut down because of a tube leak.

Note: Emission levels expressed in pounds of pollutant per million Btu were computed using the procedures of Reference Method 19 and the test results obtained during the six-run relative accuracy audit.

TABLE 5. SIX-RUN RELATIVE ACCURACY AUDIT RESULTS
FOR CEMS INSTALLED ON COAL-FIRED FGD EQUIPPED BOILER:
SOURCE S2, LSI SM810 SO₂/NO - CM50 O₂ CEMS^a

SO ₂ /O ₂ SYSTEM		
Test date	Emission level (lb/10 ⁶ Btu)	Relative accuracy ^b (%)
5/81	1.06	(+)16.0
7/81	0.91	(+)13.6
12/81	1.17	(+) 6.5
4/82	0.99	(+)11.3
11/82	1.01	(+)23.1
2/83	0.97	(+) 5.1
5/83	1.02	(+)12.2
8/83	0.89	(+)12.0
NO/O ₂ SYSTEM		
Test date	Emission level (lb/10 ⁶ Btu)	Relative accuracy ^b (%)
5/81	0.52	(+)14.4
7/81	0.65	(+) 6.8
12/81	0.50	(+)30.6
4/82	0.61	(+)11.6
11/82	0.67	(+)19.7
2/83	0.68	(-)12.8
5/83	0.70	(-)13.8
8/83	0.64	(-) 6.6

^aSO₂ monitor range: 0 - 1500 ppm SO₂; NO monitor range: 0 - 1000 ppm NO;
O₂ monitor range: 0 - 10% O₂ and 0 - 25% O₂.

^bThe (+) or (-) indicates whether the monitor responses were greater than, (+), or less than, (-), the reference method test results.

Note: Emission levels expressed in pounds of pollutant per million Btu were computed using the procedures of Reference Method 19 and the test results obtained during the six-run relative accuracy audit.

TABLE 6. SIX-RUN RELATIVE ACCURACY AUDIT RESULTS
FOR CEMS INSTALLED ON COAL-FIRED FGD EQUIPPED BOILER:
SOURCE C, CONTRAVES GOERZ GEM-100 SO₂/NO/CO₂ CEMS^a

SO ₂ /CO ₂ SYSTEM		
Test date	Emission level (lb/10 ⁶ Btu)	Relative accuracy ^b (%)
5/83	0.21	(-) 6.2% of standard ^c
8/83	1.05	(+) 13.8
11/83	1.57	(-) 2.1

NO/CO ₂ SYSTEM		
Test date	Emission level (lb/10 ⁶ Btu)	Relative accuracy ^b (%)
5/83	0.99	(+) 36.2
8/83	0.99	(+) 37.4
11/83	1.04	(+) 16.5

^aSO₂ channel range: 0 - 750 ppm SO₂; NO channel range: 0 - 1000 ppm NO;
CO₂ channel range: 0 - 20% CO₂.

^bThe (+) or (-) indicates whether the monitor responses were greater than, (+), or less than, (-), the reference method test results.

^cThe RAA was found to be 35.1% of the mean reference method value and 6.2% of the applicable standard (1.2 lb/10⁶ Btu) for this audit. These results demonstrate that the CEM is "in control" according to the Appendix F, Procedure 1 criteria.

^dThe source does not normally utilize, record, or report data provided by the NO_x monitoring system. The output of the NO_x CEM was recorded for this testing program at the request of the EPA Quality Assurance Division.

Note: Emission levels expressed in pounds of pollutant per million Btu were computed using the procedures of Reference Method 19 and the test results obtained during the six-run relative accuracy audit.

TABLE 7. SIX-RUN RELATIVE ACCURACY AUDIT RESULTS
FOR CEMS INSTALLED ON COAL-FIRED FGD EQUIPPED BOILER:
SOURCE W, KVB SO₂/NO_x/CO₂ CEMS^a

INLET ^b		
SO ₂ /CO ₂ SYSTEM		
Test date	Emission level (lb/10 ⁶ Btu)	Relative accuracy ^c (%)
8/83	0.80	(+)13.8

INLET ^b		
NO _x /CO ₂ SYSTEM		
Test date	Emission level (lb/10 ⁶ Btu)	Relative accuracy ^c (%)
8/83	0.57	(-)21.0

^aThe KVB CEMS at Source W is comprised of: (1) a Western Research Model 721 SO₂ analyzer, (2) a Thermo Electron Model 10AR NO_x analyzer, and (3) a Fuji Electric Model 3200 CO₂ analyzer. The monitor ranges are as follow. SO₂ channel range: 0 - 500 ppm SO₂; NO_x channel range: 0 - 1000 ppm NO_x; CO₂ channel range: 0 - 20% CO₂. Source W is subject to Subpart Da, 40 CFR 60.

^bOnly the inlet sampling location could be tested during the initial audit (8/83) because of stack elevator problems. The inlet and outlet emission levels are determined using the same analyzers.

^cThe (+) or (-) indicates whether the monitor responses were greater than, (+), or less than, (-), the reference method test results.

Note: Emission levels expressed in pounds of pollutant per million Btu were computed using the procedures of Reference Method 19 and the test results obtained during the six-run relative accuracy audit.

SECTION 3

CYLINDER GAS AUDITS (CGA)

3.1 CGA Requirements in Appendix F, Procedure 1

The requirements of Appendix F, Procedure 1 for CGA are:

"6.1.2 Cylinder Gas Audit. Every other calendar quarter (i.e., semiannually perform the audit either by using cylinder gases or by using an EPA-approved alternative method instead of the RAA. However, use the RAA at least every other calendar quarter (semiannually)).

Conduct a CGA as follows:

1. Challenge each monitor (both pollutant and diluent, if applicable) with an audit gas of known concentration at two points within the following ranges:

Audit point	Pollutant monitors	Diluent monitors	
		CO ₂	O ₂
1	20 to 30% of monitor calibration full scale	5 to 8% by volume	4 to 6% by volume
2	50 to 60% of monitor calibration full scale	10 to 14% by volume	8 to 12% by volume

Use a separate audit gas cylinder for audit points 1 and 2. Do not dilute gas from the audit cylinder when challenging the monitor.

The monitor should be challenged at each audit point for a sufficient period of time to assure that adsorption-desorption of the monitoring system surfaces has stabilized.

2. Operate each monitor in its normal sampling mode (i.e., pass the audit gas through all filters, scrubbers, conditioners, and other monitor components used during normal sampling and as much of the sampling probe as is practical)."

The control limit for the CGA is provided in Section 6.2:

"If the inaccuracy exceeds ± 15 percent using the CGA, the CEMS is 'out of control.'"

When the performance audit program was initiated, the CGA audit points specified by Appendix F were: (1) 45 to 55% and 85 to 95% of pollutant monitor span, (2) 5 to 8% CO₂ and 10 to 14% CO₂, and (3) 1 to 3% O₂ and 6 to 10% O₂. CGAs conducted during the initial phase of this testing program included these audit points and an additional audit point at (1) 20 to 30% of pollutant monitor span, and (2) either the span or mid range level for the diluent monitor. Thus, some of the data obtained during the audit program are not consistent with the current Appendix F, Procedure 1 CGA audit point specifications.

3.2 Summary of CGA Results

Table 8 summarizes CGA results for four SO₂ and three NO_x CEMS installed on four coal-fired boilers equipped with FGD systems. The CGAs were conducted during the same field tests as the RAAs for the LSI and DuPont monitors. (See Tables 1 through 7 for RAA results.) Contraves Goerz and EDC monitors do not accept calibration gases; therefore, the CGA was not performed for these CEMS.

3.3 Analysis of CGA Results

Of the 23 SO₂ monitor CGAs, 20 CGA results showed that the CEM was within the $\pm 15\%$ CGA limit of Appendix F. Of the 16 NO_x monitor CGAs, 12 audits showed that the CEMS were capable of meeting the $\pm 15\%$ CGA limit at all test points.

Of 22 O₂ channel CGAs, 10 failed to meet the $\pm 15\%$ limit for at least one point. Nine of the ten failures were audits in which the audit gas concentration was $< 2.8\%$ O₂, thereby allowing a maximum deviation of only 0.42% O₂ in the monitor response in order to meet the $\pm 15\%$ CGA limit. In each case where this problem occurred, audit point 2 was within the $\pm 15\%$ limit. In the only other case where any of the O₂ CGA results exceeded the $\pm 15\%$ limit, the monitor failed the CGA at both audit point 2 and the additional audit point (20.9% O₂).

The DuPont SO₂ monitor met the CGA limit for six of the seven tests performed. The one failure was caused by a CGA result of 16.4% at audit point 1. The monitor met the CGA limit at audit point 2 for this test.

The LSI SO₂ monitor at Source S1 passed all seven CGAs at audit point 1, audit point 2, and at the additional audit point.^a (The May 1983 15.3% CGA result at audit point 1 is within the $\pm 15\%$ CGA limit when results are rounded to two significant figures.) The LSI SO₂ monitor at Source S2 passed the CGA limit for all of the five tests at audit point 1, six of the seven tests at audit point 2, and seven of the eight tests at the additional audit point. The single failure at audit point 2 and at the additional audit point occurred during the same test, at which time the monitor was observed to greatly exceed the CGA limit of $\pm 15\%$.

The LSI NO monitor at Source S1 was within the CGA limit of $\pm 15\%$ for three of the five tests at audit point 1, five of seven tests at audit point 2, and six of seven tests at the additional audit point. The monitor failed the CGA at all three audit points for one test. The monitor passed the CGA at the additional audit point during a test where failure at both audit point 1 and audit point 2 was observed. The LSI NO monitor at Source S2 passed the CGA audit for all of the five tests at audit point 1, seven of the eight tests at audit point 2, and seven of the eight tests at the additional audit point. The failures at audit point 2 and the additional audit point did not occur during the same test.

The KVB NO_x and CO₂ monitors at Source W were within the CGA limit for all three audit points during the single audit that was performed. The KVB SO₂ monitor failed the CGA at audit point 1.

^a Results of the manufacturer certification for the initial Performance Specification Test are not included in the CGA analysis for any of the LSI SO₂ or NO monitors. These data do not necessarily reflect representative CGA results for the installed monitors.

TABLE 8. CYLINDER GAS AUDIT RESULTS
FOR CEMS INSTALLED ON COAL-FIRED, FGD EQUIPPED BOILERS

Source code/test number	Test date	CEM type	Monitor channel	Audit Point 1a		Audit Point 2a		Additional Audit Pointa	
				Cylinder gas concentration (ppm or %)	CGA result ^b (%)	Cylinder gas concentration (ppm or %)	CGA result ^b (%)	Cylinder gas concentration ^c (ppm or %)	CGA result ^b (%)
S1/1c	7/81	LSI	SO ₂ NO O ₂	--	--	794	(-)11.2	1314	(-) 9.8
				--	--	440	(-)13.6	900	(-)15.0
				5.4	(+) 1.9	8.3	(+) 2.4	0.9	(+)10.5
S1/2	12/81	LSI	SO ₂ NO O ₂	--	--	776	(+)10.2	1185	(+)12.1
				--	--	458	(+) 5.9	911	(-) 1.2
				1.1	(-) 9.1	7.9	(+) 1.3	20.9	(-) 0.5
S1/3	5/82	LSI	SO ₂ NO O ₂	377	(+)11.4	863	(+)10.9	1293	(+)11.4
				253	(-)13.0	455	(-)14.3	899	(-)11.0
				5.0	(-) 8.0	8.3	(-) 7.7	1.0	(-)21.6
S1/4	11/82	LSI	SO ₂ NO O ₂	494	(+) 6.3	--	--	1192	(+) 5.7
				290	(-) 8.6	453	(-) 5.1	905	(-) 2.2
				2.7	(+) 7.4	12.6	(+) 4.0	20.9	(+) 4.8
S1/5	2/83	LSI	SO ₂ NO O ₂	492	(+) 5.9	817	(+) 4.6	1303	(+) 6.5
				290	(-)17.2	453	(-)17.2	692	(-)14.7
				5.0	(+) 3.0	8.0	(+) 0.6	1.8	0.0
S1/6	5/83	LSI	SO ₂ NO O ₂	372	(-)15.3	867	(-)12.6	1303	(-)10.7
				224	(+)33.9	448	(+)25.0	917	(+)17.8
				5.0	(+) 6.0	8.3	(+) 4.8	1.8	(+) 2.8
S1/7	8/83	LSI	SO ₂ NO O ₂	270	(+) 5.6	886	(+) 3.3	1278	(+) 4.5
				225	(-) 7.1	444	(-) 3.2	902	(-) 4.2
				2.8	(-)10.7	12.5	0.0	20.9	(-) 4.3

(continued)

TABLE 8. continued

Source code/test number	Test date	CEM type	Monitor channel	Audit Point 1 ^a		Audit Point 2 ^a		Additional Audit Point ^a	
				Cylinder gas concentration (ppm or %)	CGA result ^b (%)	Cylinder gas concentration (ppm or %)	CGA result ^b (%)	Cylinder gas concentration (ppm or %)	CGA result ^b (%)
S2/1 ^c	5/81	LSI	SO ₂ NO ₂ O ₂	--	--	794	(+) 0.1	1300	(-) 1.9
				--	--	530	(-) 0.9	900	(-) 3.3
				5.4	(-) 0.6	8.3	(+) 1.4	0.9	(-) 1.2
S2/2	7/81	LSI	SO ₂ NO ₂ O ₂	--	--	794	(+) 2.6	1314	(+) 5.6
				--	--	440	(+) 4.1	900	(-) 3.7
				5.4	(+) 4.1	8.3	(+) 4.8	0.9	(+) 2.3
S2/3	12/81	LSI	SO ₂ NO ₂ O ₂	--	--	776	(+) 51.8	1185	off-scale
				--	--	458	(+) 35.4	911	(+) 7.8
				1.1	0.0	7.9	(+) 17.7	20.9	(+) 21.1
S2/4	4/82	LSI	SO ₂ NO ₂ O ₂	368	(+) 1.9	863	(+) 4.3	1188	(+) 4.8
				253	(-) 11.1	458	(+) 0.9	911	(-) 7.2
				5.1	(+) 7.1	8.4	(+) 11.9	1.0	(+) 18.0
S2/5	11/82	LSI	SO ₂ NO ₂ O ₂	494	(+) 0.2	--	--	1192	(+) 7.0
				290	(+) 6.9	453	(+) 1.5	905	(-) 6.6
				2.7	(+) 25.9	12.6	(+) 10.3	20.9	(+) 9.6
S2/6	2/83	LSI	SO ₂ NO ₂ O ₂	492	(+) 2.2	817	(+) 2.8	1303	(+) 3.6
				290	(-) 5.2	453	(-) 8.4	692	(-) 13.3
				5.0	(+) 1.0	8.0	0.0	1.8	(-) 5.6
S2/7	5/83	LSI	SO ₂ NO ₂ O ₂	372	(+) 3.0	867	(+) 2.1	1303	(+) 4.8
				224	(-) 6.3	448	(-) 10.7	917	(-) 17.1
				5.0	(-) 2.0	8.3	(+) 1.2	1.8	(+) 11.1

(continued)

TABLE 8. continued

Source code/test number	Test date	CEM type	Monitor channel	Audit Point 1 ^a		Audit Point 2 ^a		Additional Audit Point ^a	
				Cylinder gas concentration (ppm or %)	CGA result ^b (%)	Cylinder gas concentration (ppm or %)	CGA result ^b (%)	Cylinder gas concentration (ppm or %)	CGA result ^b (%)
S2/8	8/83	LSI	SO ₂ NO ₂ O ₂	270 225 2.8	0.0 (-) 0.4 (-) 39.3	886 444 12.5	(-) 0.1 (-) 5.4 (-) 9.6	1278 902 20.9	(+) 12.7 (-) 14.2 (-) 2.4
A/O ^d	1/81 ^e	DuPont	SO ₂ O ₂	-- 0.9	-- (+) 25.0	213 8.3	(-) 5.2 (-) 5.8	377 20.9	(-) 1.9 (-) 3.8
A/1	11/81	DuPont	SO ₂ O ₂	-- 0.8	-- (+) 25.0	197 8.0	(-) 2.0 (-) 1.3	390 20.9	(-) 4.9 (+) 3.8
A/2	4/82	DuPont	SO ₂ O ₂	110 2.7	(+) 9.1 (+) 22.2	236 7.8	(+) 3.8 (+) 2.6	368 20.9	(+) 6.0 (-) 1.4
A/3	8/82	DuPont	SO ₂ O ₂	110 2.7	(-) 16.4 (-) 3.7	204 7.8	(-) 1.0 (-) 2.6	377 20.9	(+) 3.2 (-) 0.5
A/4	11/82 ^f	DuPont	--	--	--	--	--	--	--
A/5	4/83	DuPont	SO ₂ O ₂	94 1.8	(+) 8.5 (-) 16.7	233 12.5	(+) 5.6 (-) 4.8	369 20.9	(+) 4.1 (-) 0.5
A/6	7/83	DuPont	SO ₂ O ₂	108 1.8	(-) 3.7 (-) 16.7	192 12.5	0.0 0.0	368 20.9	(+) 1.6 (+) 4.8
A/7	11/83	DuPont	SO ₂ O ₂	95 3.7	(+) 1.0 (-) 8.1	192 12.5	(+) 1.0 (-) 0.8	372 20.9	(-) 3.8 (+) 1.0
W/1(I) ^g	8/83	KVB	SO ₂ NO ₂ CO ₂	108 225 4.9	(+) 20.3 (-) 14.7 (+) 4.1	270 444 11.2	(+) 10.0 (-) 12.2 (-) 2.7	492 902 17.9	off scale (-) 11.7 (-) 2.2

(continued)

TABLE 8. continued

a values for audit points 1 and 2 are specified in Appendix F. The additional audit point is not required in the current draft of Appendix F. For the tests conducted, this audit point was usually about 90% of the monitor full scale value for pollutant monitors.

b The (+) or (-) indicates whether the monitor responses were greater than, (+), or less than, (-), the cylinder gas concentrations.

c SO₂ monitor range: 0 - 1500 ppm SO₂, NO monitor range: 0 - 1000 ppm NO; O₂ monitor range: 0 - 10% O₂ and 0 - 25% O₂.

d SO₂ monitor range: 0 - 400 ppm SO₂; O₂ monitor range: 0 - 25% O₂.

e The data presented were obtained from Initial Performance Specification Test of installed CEM. All other test results for this source were obtained during the Appendix F audit program.

f No valid data obtained during this audit because of process/control system upset conditions.

g SO₂ monitor range: 0 - 500 ppm SO₂; NO_x monitor range: 0 - 1000 ppm NO_x. CO₂ monitor range: 0 to 20% CO₂.

SECTION 4

CGA vs. RAA: SUMMARY AND COMPARISON OF RESULTS

As stated in Appendix F, Procedure 1, and cited in Section 3.1 of this report, the source has the option to use a CGA instead of an RAA every other calendar quarter (i.e., semiannually) for those monitors that accept calibration gases. CGAs and RAAs were conducted for each audit of the LSI, DuPont, and KVB CEMS; therefore, a comparison of these results is presented.

4.1 Summary of CGA and RAA Results

Table 9 summarizes CGA and RAA results for LSI, DuPont, and KVB SO₂ and NO_x CEMS. The RAA actually measures the boiler emission rate for the pollutant of interest (either SO₂ or NO_x); therefore, only the CGA audit points closest to the effluent concentrations were used to compare CGA and RAA results. This point is most often audit point 1 from the CGA; however, because audit point 1 was not included at the beginning of the test program, other data have been used in some cases. Results for the CGAs at all audit points are presented in Table 8.

4.2 Comparison of CGA and RAA Results

The results of the RAA and CGA are considered to agree when both accuracy assessment methods provide the same indication of the status of the monitor. Thus, where both the RAA and CGA results indicate the CEM is "in control" or where both audit methods indicate the CEM is "out-of-control," the results are considered to agree.

CGAs and RAAs were conducted during the same field tests on six occasions for the DuPont SO₂ CEMS. On two occasions the DuPont CEMS failed the RAA, but passed the CGA.

There are 14 Lear Siegler NO CEMS CGA vs. RAA comparisons. All of the 14 comparisons indicate agreement between the CGA and RAA results.

Of the 14 Lear Siegler SO₂ CEMS CGA vs. RAA comparisons conducted, 11 indicated agreement. (The CGA result of 15.3% for the SO₂ channel, Source S1, May 1983, is within the $\pm 15\%$ CGA limit when results are rounded to two significant figures.) For the other three cases, the SO₂ CEMS failed the RAA but passed the CGA on two occasions, and passed the RAA but failed the CGA on one occasion.

A CGA and RAA were conducted during the one field test of the KVB SO₂/NO_x CEM system. Both SO₂ and NO_x CEMS indicated agreement between the CGA and RAA results.

TABLE 9. COMPARISON OF CYLINDER GAS AUDIT RESULTS AND SIX-RUN RELATIVE ACCURACY
AUDIT RESULTS FOR CEMS INSTALLED ON COAL-FIRED, FGD EQUIPPED BOILERS

Source code/ test number	Test date	CEM type	Monitor channel	Relative accuracy audit			Cylinder gas audit		
				Emission level ^a (ppm, %, or lb/10 ⁶ Btu)	RA result ^b (%)	Audit point ^c	Cylinder gas concentration ^d (ppm or %)	CGA result ^e (%)	
SI/1	7/81	LSI	SO ₂ NO ₂ O ₂ SO ₂ /O ₂ NO/O ₂	433		2	794	(-)11.2	
				407		2	440	(-)13.6	
				7.6		1	5.4	(+) 1.9	
				1.10	(+)18.6				
				0.74	(-) 4.3				
SI/2	12/81	LSI	SO ₂ NO ₂ O ₂ SO ₂ /O ₂ NO/O ₂	476		2	776	(+)10.2	
				311		2	458	(+) 5.9	
				7.3		2	7.9	(+) 1.3	
				1.18	(+) 8.9				
				0.56	(+)22.9				
SI/3	5/82	LSI	SO ₂ NO ₂ O ₂ SO ₂ /O ₂ NO/O ₂	445		1	377	(+)11.4	
				408		2	455	(-)14.3	
				7.2		1	5.0	(-) 8.0	
				1.10	(+)26.7				
				0.73	(-)16.4				
SI/4	11/82	LSI	SO ₂ NO ₂ O ₂ SO ₂ /O ₂ NO/O ₂	350		1	494	(+) 6.2	
				319		1	290	(-) 8.6	
				7.3		2	12.6	(+) 4.0	
				0.87	(+)35.9				
				0.57	(+)10.8				
SI/6	5/83	LSI	SO ₂ NO ₂ O ₂ SO ₂ /O ₂ NO/O ₂	456		1	372	(-)15.3	
				325		1	224	(+)33.9	
				7.3		1	5.0	(+) 6.0	
				1.14	(-)12.2				
				0.58	(+)25.9				

(continued)

TABLE 9. continued

Source code/test number	Test date	CEM type	Monitor channel	Relative accuracy audit		Cylinder gas audit		
				Emission level ^a (ppm, %, or lb/10 ⁶ Btu)	RA result ^b (%)	Audit point ^c	Cylinder gas concentration ^d (ppm or %)	CGA result ^e (%)
S1/7	8/83	LSI	SO ₂	358		1	270	(+) 5.6
			NO ₂	335		1	225	(-) 7.1
			O ₂	8.2		2	12.5	0.0
			SO ₂ /O ₂ NO/O ₂	0.95 0.64	(+)22.0 (+) 9.0			
S2/1	5/81	LSI	SO ₂	453		2	794	(+) 0.1
			NO	309		2	530	(-) 0.9
			O ₂	6.5		1	5.4	(-) 0.6
			SO ₂ /O ₂ NO/O ₂	1.06 0.52	(+)16.0 (+)14.4			
S2/2	7/81	LSI	SO ₂	388		2	794	(+) 2.6
			NO	388		2	440	(+) 4.1
			O ₂	6.5		1	5.4	(+) 4.1
			SO ₂ /O ₂ NO/O ₂	0.92 0.66	(+)12.2 (+) 5.0			
S2/3	12/81	LSI	SO ₂	474		2	776	(+)51.8
			NO	286		2	458	(+)35.4
			O ₂	7.2		2	7.9	(+)17.7
			SO ₂ /O ₂ NO/O ₂	1.17 0.50	(+) 6.5 (+)30.6			
S2/4	4/82	LSI	SO ₂	408		1	368	(+) 1.9
			NO	347		1	253	(-)11.1
			O ₂	6.9		1	5.1	(+) 7.1
			SO ₂ /O ₂ NO/O ₂	0.99 0.61	(+)11.3 (+)11.6			

(continued)

Table 9. continued

Source code/test number	Test date	CEM type	Monitor channel	Relative accuracy audit		Cylinder gas audit		
				Emission level ^a (ppm, %, or lb/10 ⁶ Btu)	RA result ^b (%)	Audit point ^c	Cylinder gas concentration ^d (ppm or %)	CGA result ^e (%)
S2/5	11/82	LSI	SO ₂	387		1	494	(+) 0.2
			NO	360		1	290	(+) 6.9
			O ₂	7.8		2	12.6	(+) 10.3
			SO ₂ /O ₂	1.01	(+) 23.1			
S2/6	2/83	LSI	NO/O ₂	0.67	(+) 19.7			
			SO ₂	370		1	492	(+) 2.2
			NO	363		1	290	(-) 5.2
			O ₂	8.2		1	5.0	(+) 1.0
			SO ₂ /O ₂	0.97	(+) 5.1			
S2/7	5/83	LSI	NO/O ₂	0.68	(-) 12.8			
			SO ₂	376		1	372	(+) 3.0
			NO	358		2	448	(-) 10.7
			O ₂	8.4		1	5.0	(-) 2.0
			SO ₂ /O ₂	1.14	(+) 12.2			
S2/8	8/83	LSI	NO/O ₂	0.58	(-) 13.8			
			SO ₂	333		1	270	0.0
			NO	337		1	225	(-) 0.4
			O ₂	8.2		2	12.5	(-) 9.6
			SO ₂ /O ₂	0.89	(+) 12.0			
A/1	11/81	DuPont	NO/O ₂	0.64	(-) 6.6			
			SO ₂	146		2	197	(+) 4.8
			O ₂	12.2		2	8.0	(-) 1.3
			SO ₂ /O ₂	0.57	(+) 9.5			
			SO ₂	133		1	110	(+) 9.1
A/2	4/82	DuPont	O ₂	9.4		2	7.8	(+) 2.6
			SO ₂ /O ₂	0.39	(+) 19.7			
			SO ₂					

(continued)

TABLE 9. continued

Source code/test number	Test date	CEM type	Monitor channel	Relative accuracy audit			Cylinder gas audit		
				Emission level ^a (ppm, %, or lb/10 ⁶ Btu)	RA result ^b (%)	Audit point ^c	Cylinder gas concentration ^d (ppm or %)	CGA result ^e (%)	
A/3	8/82	DuPont	SO ₂	171		2	204	(-) 1.0	
			O ₂	9.0		2	7.8	(-) 2.6	
			SO ₂ /O ₂	0.49	(+)34.7				
A/5	4/83	DuPont	SO ₂	164		2	233	(+) 5.6	
			O ₂	9.1		2	12.5	(-) 4.8	
			SO ₂ /O ₂	0.47	(-)13.6				
A/6	7/83	DuPont	SO ₂	162		2	192	0.0	
			O ₂	9.0		2	12.5	0.0	
			SO ₂ /O ₂	0.46	(+)18.7				
A/7	11/83	DuPont	SO ₂	127		1	95	(+) 1.0	
			O ₂	10.3		2	12.5	(-) 0.8	
			SO ₂ /O ₂	0.41	(+)53.7				
W/1(I)	8/83	KVB	SO ₂	359		2	270	(+)10.0	
			NO _x	376		2	444	(-)12.2	
			CO ₂	13.4		2	11.2	(-) 2.7	
			SO ₂ /CO ₂	0.80	(+)13.8				
			NO _x /CO ₂	0.57	(-)21.0				

(continued)

TABLE 9. continued

^aSO₂ and NO data are expressed in parts per million; O₂ and CO₂ data are expressed as percent O₂ or CO₂; and SO₂/O₂, NO/O₂, SO₂/CO₂, and NO/CO₂ data are expressed as lb/10⁶ Btu.

^bThe (+) or (-) indicates whether the monitor responses were greater, (+), or less than, (-), the reference method test results.

^cThe CGA audit point selected for comparison with RAA results most closely approximates the effluent concentration.

^dSO₂ and NO cylinder gas concentrations are expressed in parts per million; O₂ and CO₂ cylinder gas concentrations are expressed as percent O₂ or CO₂.

^eThe (+) or (-) indicates whether the monitor responses were greater, (+), or less than, (-), the cylinder gas concentration.